Highlights of AGTSR Thermal Barrier Coatings Research At The University of Connecticut

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Abstract

The University of Connecticut has received four prime contracts for thermal barrier coatings (TBC) research under the AGTSR Program, two of which are still underway. Substantial research and development progress has been made in a number of areas, including:

(a) Mechanisms-Based Research.
(b) Identifying Coating Defects As Sites Where Spallation Damage Initiates.
(c) Demonstrating That Significant Life Improvements Can Be Achieved By Reducing or Eliminating These Coating Defects.
(d) Development Of Photoluminescence Piezospectroscopy (PLPS) As A Promising Non-Destructive Inspection Technique For TBCs.
(e) Development of PLPS As A Promising Techniques For Assessing Life Remaining For Service Blades And As Basis For Lifetime Prediction Systems.
(f) Development of An Advanced TBC, Gadolinium Zirconate, With Reduced Thermal Conductivity and Higher Use Temperature.

This abstract highlights the results of this research to date.

Under the AGTSR program, the University of Connecticut has pioneered mechanisms-based research in order to (1) identify where and how spallation is initiated in various TBCs, (2) extend TBC spallation life by eliminating the defects associated with damage initiation, (3) apply the actual spallation mechanisms to realistic lifetime prediction models. A total of 6 plasma spray (PS) and electron beam physical vapor deposition (EB-PVD) TBCs have been investigated.

In Pt-Al/EB-PVD TBCs, damage initiation occurred at grain boundary ridges formed on the surface of the Pt-Al bond coat during the chemical vapor deposition of Al. When these ridges were removed, a four-fold improvement in spallation life was obtained. The stress around these ridges has been quantitatively modeled and it has been shown that failure occurs in specimens with a variety of ridge heights at a constant value of the out-of-plane tensile stress.

In CoNiCrAlY/EB-PVD TBCs, damage initiation was at entrapped oxides extending from the bond coat surface. With slight modification to bond coat processing, the effects of these embedded oxides was alleviated and a 40 times improvement in spallation life was obtained.

These two examples show the magnitude of the benefit of using mechanisms based research to extend TBC life.

In plasma sprayed coatings, the mechanisms-based research shows that damage initiation is occurring at the peaks of the bond coat surface roughness and that crack extension and link-up is occurring in the splat boundaries of the ceramic layer. The effect of surface roughness has been modeled and it has been suggested that significant improvement in the spallation life of PS TBCs can be achieved with optimization of surface roughness and toughening of ceramic splat boundaries located near the bond coat.

In conjunction with the mechanisms-based research, the University of Connecticut has done extensive research and development of a non-destructive inspection technique (NDI) for (a) identifying incipient damage and (b) for use in conjunction with development of lifetime prediction methods. The NDI technique is the Photoluminescence Piezospectroscopy (PLPS) technique in which an argon ion laser is used to fluorescence the chromia ions in the thermally grown oxide (TGO, alpha alumina layer) that forms between the bond coat and the ceramic. The fluorescence spectra provides the level of stress in TGO, which has been determined as a function of thermal cycles for 6 EB-PVD and PS TBCs. The change in stress with cycles is unique for each TBC and can be used to detect incipient damage and to determine life remaining. The PLPS technique has been successfully demonstrated on service-run turbine blades and vanes. A portable PLPS instrument has been demonstrated and is under further development for use by engine manufacturers, repair shops and coating suppliers.

In addition to extending the life of current TBCs, research is underway to develop an advanced TBC with reduced thermal conductivity, higher use temperature and improved hot corrosion resistance. After data base screening of a 150 compositions and experimental evaluation of 4 of the best compositions, two gadolinium zirconate ceramic compositions has been selected as promising for further evaluation in cyclic durability.

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